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Woody angiosperm diversity and indigenous conservation in Ghimbo Pomuan Sacred Forest, Kampar, Riau Province, Indonesia

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Abstract. *Hidayah H, Setiowati FK, Adinugraha F, Zubaidah S. 2025. Woody angiosperm diversity and indigenous conservation in Ghimbo Pomuan Sacred Forest, Kampar, Riau Province, Indonesia. Biodiversitas 26: 6240-6251.* Woody angiosperms are the dominant component of tropical forest biodiversity, with important ecological, cultural, and economic roles. However, their conservation remains challenging, particularly in sacred forests managed under customary systems that are underdocumented in scientific literature. The Ghimbo Pomuan Sacred Forest in Kampar, Riau Province, Indonesia, offers an opportunity to explore the biocultural relationships between people and woody plant species. This study aimed to document woody angiosperm diversity in the Ghimbo Pomuan Sacred Forest and examine indigenous conservation practices at the forest level. Field exploration combined vegetation sampling in 35 plots (20 x 20 m) and semi-structured interviews with indigenous elders. We recorded 30 woody angiosperm species from 18 families, with Myrtaceae and Dipterocarpaceae being the most dominant. Species diversity was moderate (H′ = 2.637-2.915), with 24 genera and several species holding global conservation concern, such as *Rubroshorea uliginosa* (Endangered), *Rubroshorea balangeran* (Vulnerable), and *Madhuca ovata* (Critically Endangered). Indigenous management practices include customary prohibitions, collective governance (*sekepomuan*), and sanctions for violating these rules. Particular species, such as *Syzygium* spp. and *Gluta renghas*, were protected for both ecological and spiritual reasons, supporting natural regeneration and forest succession. This study underscores the importance of incorporating indigenous knowledge into conservation policies and reaffirms the significance of sacred forests as vital refuges for biodiversity.

Keywords: Biodiversity, ethnobotany, Ghimbo Pomuan Sacred Forest, indigenous knowledge, Kampar

INTRODUCTION

Woody angiosperms are one of the plant groups that play a crucial role in the ecosystems. As flowering plants that dominate terrestrial ecosystems, angiosperms provide food, oxygen, carbon storage, and habitat for various life forms (Bahadur et al. 2015; Ying 2021; Stephens et al. 2023; Mo et al. 2024). Taxonomically, they are classified as monocots and dicots (Perner and Wachtier 2020), accounting for nearly 90% of all land plant species (Sauquet et al. 2022), making them key to forest structure and function. Their reproductive system in the form of flowers makes them ecologically and evolutionarily important (Rahmayani et al. 2020). Among them, woody angiosperms are defined as flowering plants with lignified stem tissues, including trees, shrubs, lianas, bamboos, and palms, but excluding exclusively herbaceous families (Kusumoto et al. 2023). They are central to the structure, carbon storage, and regeneration of tropical forests.

In many regions, these ecological roles are sustained within community-protected areas, particularly sacred forests, which combine biodiversity conservation with indigenous knowledge. Indigenous knowledge refers to a set of practices, beliefs, taboos, and ecological ethics that help regulate and conserve nature (Adam et al. 2019; Cajete 2020). Sacred forests are defined as forested areas protected by customary beliefs, rituals, and spiritual values. This knowledge directly protects biodiversity by shaping how local communities interact with their environment. It includes classification of landscape features, management rituals, spiritual prohibitions, and species-specific uses (Wilder 2016; Kosoe et al. 2020). Local people utilize angiosperm species for food (Delaney and von Wettberg 2023), medicine (Liu et al. 2023), and building materials (Berame et al. 2021), and their survival is closely tied to traditions passed down through generations.

Sacred forests in several countries, such as India (Sharma and Kumar 2020; Sen and Bhakat 2022) and Iran (Shakeri et al. 2021) are recognized as biocultural refugia, hosting rare, endemic, and ethnobotanically significant plant species. However, studies in Southeast Asia remain limited (Undaharta et al. 2025), and threats such as land conversion, logging, and erosion of indigenous traditions pose significant risks to these forests. In Indonesia, sacred forest research has grown in Bali, Sulawesi, and Kalimantan (Akhmar et al. 2022; Mulyadi et al. 2022). For example, Santhyami et al. (2021) reported that the sacred forest of Bukit Badindiang in West Sumatra sustains tree diversity and carbon stocks, while Riziqo et al. (2024) highlighted the role of mythology and sacred values in forest protection among the Karo community in North Sumatra. Similarly, Sinambela et al. (2021) showed that traditional beliefs in the Sibaganding Tua sacred forest restrict tree cutting and secure water sources and plant resources. These findings confirm that sacred forests are effective in conserving both biodiversity and cultural heritage.

The Ghimbo Pomuan Sacred Forest is one such forest governed by indigenous institutions in Kampar, Riau Province, Indonesia. Several studies have been conducted in this area, such as non-timber forest products (Shadrina et al. 2023), the spatial distribution of medicinal plants (Ikhsani et al. 2023), and carbon valuation (Ratnaningsih et al. 2023). However, documentation of woody angiosperm diversity and its relationship with indigenous ecological knowledge remains scarce. Furthermore, understanding the cultural logic behind sacred forest governance can strengthen biodiversity policy by aligning conservation goals with community worldviews (Harada et al. 2022; Fikri 2023). This alignment is critical in relation to woody angiosperm diversity and indigenous conservation, which is still rare in the Ghimbo Pomuan Sacred Forest. Therefore, this study aimed to document the diversity of woody angiosperms in the Ghimbo Pomuan Sacred Forest and analyze indigenous conservation practices at the forest level. By integrating floristic data with cultural perspectives, this study fills a knowledge gap and contributes to the ecological and socio-cultural understanding of sacred forests in Sumatra.

MATERIALS AND METHODS

Study area

This research was conducted in January 2025 in the Ghimbo Pomuan Sacred Forest area (0°19′52″ N; 101°13′01″ E), Koto Perambahan Village, Kampar Sub-district, Kampar District, Riau Province, Indonesia (Figure 1). The Ghimbo Pomuan Sacred Forest is part of the customary territory of the Malay Kampar community and is governed by indigenous institutions through customary law. Locally, the forest is considered sacred, because it is believed to be the dwelling place of ancestral spirits; therefore, tree cutting, hunting, or land conversion are strictly regulated by customary norms. With an area of approximately 56 ha, the forest serves as a water catchment area, a source of medicinal plants, and a refuge for biodiversity. Ecologically, the forest is characterized by lowland tropical rainforest vegetation dominated by woody angiosperms, with high humidity and clay-dominated soils.

Procedures

Total area surveyed

The method used is field exploration to identify the diversity of woody angiosperms. The sampling was conducted using a stratified random sampling method. Data collection was stratified into medium (30 ha) and high (26 ha) vegetation density. This classification was derived from ArcGIS spatial analysis of forest cover, which provides pre-defined categories of vegetation density based on canopy closure and land cover characteristics. Seven transects (4 in medium, 3 in high density) with five plots each (20 × 20 m, 0.04 ha per plot; total 35 plots, 1.4 ha) with sampling intensity 2.5%. The determination of sampling intensity takes into account the energy, costs, and expertise of the researchers in the Ghimbo Pomuan Sacred Forest area. This sampling intensity falls within the Optimal Sampling Area (OSA) range of 0.24% to 4.67%, as reported in tropical forest monitoring studies, confirming that our sampling coverage is adequate to represent woody angiosperm diversity (Londe et al. 2022). GPS coordinates were recorded, and plot locations were verified in ArcGIS.

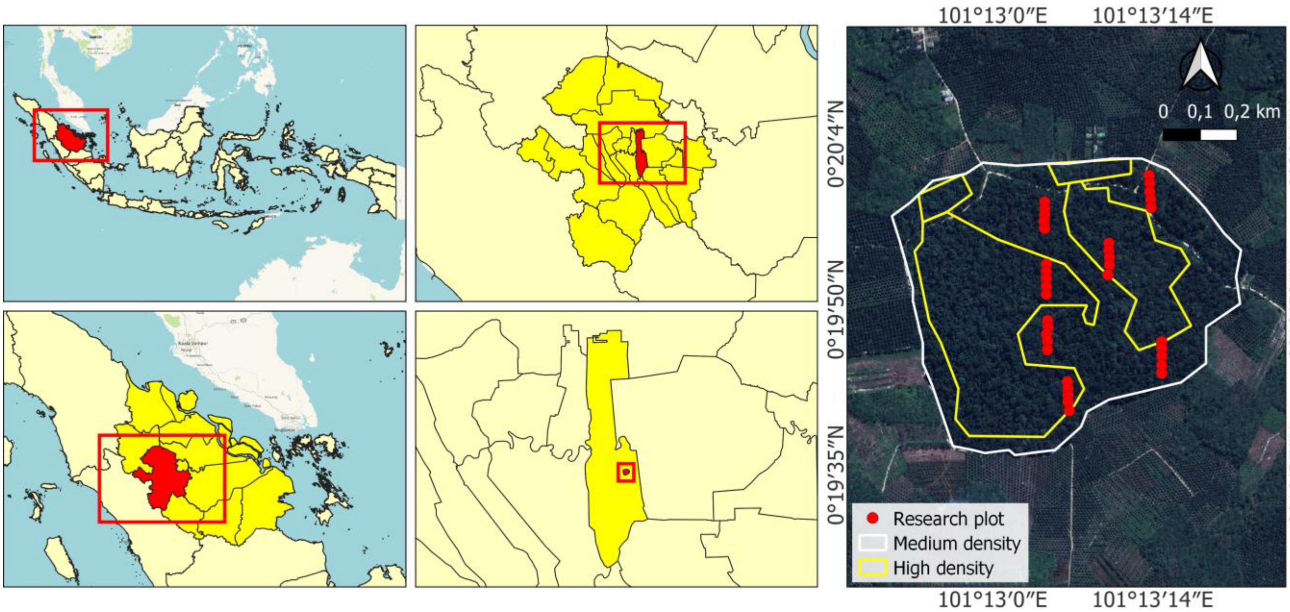

Figure 1. Study area in the Ghimbo Pomuan Sacred Forest, Koto Perambahan Village, Kampar Sub-district, Kampar District, Riau Province, Indonesia

Plant identification

Woody angiosperms were sampled using destructive methods (leaves, flowers, fruits) with permission from local authorities and community consent. Species were categorized by stem diameter of saplings < 10 cm, poles 10-19 cm, and trees ≥ 19 cm following Suryanto et al. (2021). They were identified using local names verified with elders, morphological comparison with floristic references, and online databases, Plants of the World Online (https://powo.science.kew.org/) and AsianPlant.net (https://asianplant.net/). The conservation status was confirmed through the IUCN Red List (https://www.iucnredlist.org/). A botanist at Universitas Negeri Malang (Indonesia) reviewed taxonomic validation. The researcher currently curates voucher specimens and has been scheduled for permanent deposition at the Herbarium Malangensis (MLG) at the Universitas Negeri Malang.

Indigenous knowledge

The local plant names and conservation information were obtained through interviews with traditional leaders (*Datuak Kepala Ninik Mamak* of the Kampai Tribe) as key informants. Four key informants were selected using purposive sampling based on their knowledge, with additional input from the Sacred Forest Management Institute (LPHA) and local customary treasurers. These were key informants, not survey respondents, as they were purposefully chosen for their recognized expertise on the Ghimbo Pomuan Sacred Forest.

Data analysis

The calculation of the Importance Value Index (IVI) requires three components of ecological data, namely Relative Density (RD), Relative Frequency (RF), and Relative Dominance (RD), with the formula IVI = RF + RD + Rdo (Soendjoto et al. 2025). The species Alpha Diversity index used in this study is the Shannon-Wiener Species Diversity Index (H') calculated based on the formula: $H' = -\sum p_i \log p_i$ (Odum and Barrett 2004). The similarity index used the Sørensen Similarity Index, calculated based on the formula: Index Similarity (IS) = 2C/(A+B) + 2C (Suryanto et al. 2021).

Qualitative data were reduced and grouped thematically according to two aspects, i.e., indigenous knowledge of species names and uses, and customary-based conservation mechanisms. It included an analysis of traditional norms and sanctions governing forest use, with coding of repeated themes to identify local conservation strategies that support woody angiosperm sustainability, following established ethnobiological approaches by Albuquerque et al. (2014).

RESULTS AND DISCUSSION

Species richness, composition, and dominant species

Woody angiosperms are a crucial component of plant diversity in the Ghimbo Pomuan Sacred Forest, playing a vital role in the ecosystem and the lives of local communities. The existence of these species not only reflects the region's rich biodiversity, but also serves a high ecological function and holds significant cultural value. Further understanding of the species and distribution of woody angiosperms is strengthened by indigenous knowledge, particularly through traditional systems of naming and classification.

Vegetation inventory data indicated a total of 30 woody plant species from the angiosperm group, distributed across 24 genera and spanning 18 families (Table 1; Figure 2). Dominant families included Myrtaceae (6 species), Dipterocarpaceae (4 species), Sapotaceae (3 species), Lauraceae (2 species), and Euphorbiaceae (2 species) (Figure 3). Notably, *Santiria laevigata* Blume and *Gironniera nervosa* Planch. are dominant species (8.08%), followed by *Endospermum diadenum* (Miq.) Airy Shaw and *Syzygium pycnanthum* Merr. & L.M.Perry, which dominates (6.81%).

The richness of woody angiosperms in Ghimbo Pomuan is comparable to other sacred forests in Indonesia, such as Bukit Badindiang in West Sumatra (Santhyami et al. 2021) and Sibaganding Tua in North Sumatra (Sinambela et al. 2021), and aligns with global reports from India (Sharma and Kumar 2020; Sen and Bhakat 2022) and Iran (Shakeri et al. 2021), where sacred forests function as biocultural refugia that harbor diverse and ecologically valuable tree species. This pattern suggests that traditional protection systems and cultural taboos effectively reduce anthropogenic disturbances, allowing natural regeneration and species coexistence to persist over time.

The dominance of several families, such as Dipterocarpaceae and Myrtaceae, indicates a mature lowland forest ecosystem with stable canopy structure and fertile soils. The prevailing species, such as *S. laevigata* and *G. nervosa* are shade-tolerant taxa that thrive under limited light conditions, demonstrating adaptation to undisturbed forest environments. Thus, the high species richness and stable dominance in Ghimbo Pomuan reflect not only favorable ecological conditions but also the continued enforcement of customary laws that prevent logging and land conversion.

A summary of woody angiosperm composition and dominance in the Ghimbo Pomuan Sacred Forest is presented in Table 1. The data indicate that the forest community is characterized by species belonging to ecologically significant families such as Dipterocarpaceae, Myrtaceae, and Sapotaceae, which are typical of mature lowland tropical forests. Species exhibiting the highest Importance Value Index (IVI), including *S. laevigata*, *G. nervosa*, *E. diadenum*, and *S. pycnanthum*, represent shade-tolerant taxa that contribute to the stability and vertical stratification of the forest. Several species listed in the table also hold cultural significance and are integrated into local ethnobotanical practices, reflecting the close interaction between indigenous knowledge and forest ecology.

Table 1. Angiosperm woody plant species in the Ghimbo Pomuan Sacred Forest, Kampar, Riau Province, Indonesia

Species*	Family	Local name	Conservation status **	Number of individuals	RD (%)	Plot Found	RF (%)	Total Base Area (m²)	RD (%)	IVI (%)
Gluta renghas L.	Anacardiaceae	*Onge*	NT, Native	7	1.94	6	1.90	0.44	2.51	6.34
Santiria laevigata Blume	Burseraceae	*Lelan*	LC, Native	29	8.08	21	7.07	1.40	7.96	23.11
Gironniera nervosa Planch.	Cannabaceae	*Kolek bubu*	LC, Native	29	8.08	22	7.42	1.45	8.24	23.74
Ochanostachys amentacea Mast.	Olacaceae	*Petatal*	LC, Native	9	2.52	7	2.24	0.62	3.55	8.31
Rubroshorea leprosula (Miq.) P.S.Ashton & J.Heck.	Dipterocarpaceae	*Meranti gombuong*	NT, Native	16	4.54	14	4.66	1.22	6.94	16.14
Rubroshorea uliginosa (Foxw.) P.S.Ashton & J.Heck.	Dipterocarpaceae	*Meranti biaso*	EN, Native	16	4.54	12	3.97	0.76	4.34	12.85
Rubroshorea parvifolia (Dyer) P.S.Ashton & J.Heck.	Dipterocarpaceae	*Meranti balau*	LC, Native	14	3.95	11	3.62	0.98	5.56	13.14
Rubroshorea balangeran (Korth.) P.S.Ashton & J.Heck.	Dipterocarpaceae	*Meranti kunyik*	VU, Native	16	4.54	14	4.66	1.22	6.94	16.14
Macaranga triloba (Thunb.) Müll.Arg.	Euphorbiaceae	*Mahang*	LC, Native	3	0.84	3	1.03	0.10	0.58	2.45
Endospermum diadenum (Miq.) Airy Shaw	Euphorbiaceae	*Sendok-sendok*	LC, Native	24	6.81	21	7.07	1.76	10.02	23.90
Lithocarpus bennettii (Miq.) Rehder	Fagaceae	*Memponiong*	LC, Native	16	4.54	14	4.66	0.92	5.23	14.42
Ixonanthes icosandra Jack	Ixonanthaceae	*Pagar-Pagar*	LC, Native	4	1.13	3	1.03	0.23	1.29	3.45
Litsea erectinervia Kosterm.	Lauraceae	*Modang kapindiong*	LC, Native	3	0.84	3	1.03	0.07	0.40	2.28
Cryptocarya griffithiana Wight	Lauraceae	*Modang lasau*	LC, Introduced	11	3.11	10	3.28	0.32	1.83	8.21
Durio zibethinus L.	Malvaceae	*Duyan ojan*	DD, Native	2	0.56	2	0.69	0.13	0.74	1.99
Artocarpus integer (Thunb.) Merr.	Moraceae	*Cempedak utan*	LC, Native	1	0.28	1	0.34	0.05	0.29	0.91
Artocarpus odoratissimus Blanco	Moraceae	*Danto*	NT, Introduced	3	0.84	3	1.03	0.18	1.02	2.89
Syzygium pycnanthum Merr. & L.M.Perry	Myrtaceae	*Kolek batu*	LC, Native	24	6.81	18	6.03	0.70	3.99	16.83
Syzygium borneense (Miq.) Miq.	Myrtaceae	*Kolek jambu*	-, Introduced	2	0.56	2	0.69	0.06	0.32	1.57
Syzygium leptostemon (Korth.) Merr. & L.M.Perry	Myrtaceae	*Kolek merah*	LC, Native	14	3.95	12	3.97	0.60	3.42	11.35
Syzygium cerasiforme (Blume) Merr. & L.M.Perry	Myrtaceae	*Kolek lapi*	-, Native	7	1.94	6	1.90	0.21	1.22	5.05
Syzygium fastigiatum	Myrtaceae	*Kolek seminai*	LC, Native	5	1.43	4	1.21	0.39	2.23	4.87

Species*	Family	Local name	Conservation status **	Number of individuals	RD (%)	Plot Found	RF (%)	Total Base Area (m²)	RD (%)	IVI (%)
(Blume) Merr. & L.M.Perry										
Syzygium polyanthum (Wight) Walp.	Myrtaceae	*Solam*	LC, Native	1	0.28	1	0.34	0.22	1.23	1.85
Averrhoa carambola L.	Oxalidaceae	*Belimbiong utan*	DD, Introduced	9	2.52	7	2.24	0.30	1.68	6.45
Baccaurea macrocarpa (Miq.) Müll.Arg.	Phyllanthaceae	*Tampui*	LC, Native	2	0.56	2	0.69	0.14	0.77	2.02
Nephelium maingayi Hiern	Sapindaceae	*Ridan*	LC, Native	16	4.54	14	4.66	0.76	4.31	13.50
Madhuca ovata H.J.Lam	Sapotaceae	*Balam putioh*	CR, Native	16	4.54	14	4.66	1.20	6.85	16.05
Palaquium amboinense Burck	Sapotaceae	*Nyatuoh*	LC, Introduced	4	1.13	3	1.03	0.32	1.80	3.96
Mimusops elengi L.	Sapotaceae	*Tanjung-belukau*	LC, Native	1	0.28	1	0.34	0.10	0.57	1.20
Eurycoma longifolia Jack	Simaroubaceae	*Tongkat ali/ pasak bumi*	LC, Native	1	0.28	1	0.34	0.03	0.16	0.79

Note: *: POWO, **: IUCN red list. NT: Near Threatened, LC: Least Concern, EN: Endangered, VU: Vulnerable, DD: Data Deficient, CR: Critically Endangered. RD: Relative Density, RF: Relative Frequency, RD: Relative Dominance, IVI: Importance Value Index

Table 2. Alpha Diversity Index in each pathway/zone

Zone	Species Richness (S)	Total Individuals (N)	Shannon-Wiener Index (H′)	Interpretation
Transect 7	28 species	203	2.915	Moderate
Transect 6	26 species	200	2.830	Moderate
Transect 4	22 species	108	2.797	Moderate
Transect 3	21 species	105	2.742	Moderate
Transect 5	25 species	205	2.729	Moderate
Transect 1	20 species	105	2.710	Moderate
Transect 2	20 species	105	2.637	Moderate

Vertical stratification, regeneration, and conservation status

Based on species composition data, *E. diadenum* (24 individuals; IVI = 23.9%) was the most dominant species, followed by *S. pycnanthum* (24 individuals; IVI = 16.8%) and *Rubroshorea* species (*R. leprosula* (Miq.) P.S.Ashton & J.Heck., *R. uliginosa* (Foxw.) P.S.Ashton & J.Heck., and *R. balangeran* (Korth.) P.S.Ashton & J.Heck.) with 14-16 individuals and IVI values ranging from 12 to 14% (Table 1). These dominant taxa indicate that both pioneer and late-successional species contribute significantly to forest regeneration dynamics, which reflects the natural successional processes typically observed in tropical lowland forests. This pattern is consistent with natural succession models in tropical forests (Zhang et al. 2020). In terms of conservation status, most species were classified as Least Concern (LC) (67%), but notable species such as *R. uliginosa* (EN), *R. balangeran* and *Madhuca ovata* H.J.Lam (CR) required urgent conservation attention (Figure 4). The classification of conservation value in this study considered multiple criteria: (i) The official IUCN Red List status, (ii) The ecological role of the species (e.g., keystone, pioneer, dominant canopy), and (iii) Their socio-cultural functions, especially in local practices and beliefs. For instance, *Gluta renghas* L. is protected by spiritual taboos, while *Syzygium* spp. is both culturally and ecologically prominent. From a conservation perspective, threatened species should be prioritized not only based on IUCN status but also by recognizing their ecological importance and cultural protection through indigenous taboos and customary rules.

The dominance of LC species (67%) indicates that the Ghimbo Pomuan Sacred Forest remains ecologically stable under traditional management. However, the presence of Near Threatened, Vulnerable, Endangered, and Critically Endangered taxa also confirms its role as a biocultural refuge for rare and valuable species. Similar evidence from other Indonesian sacred forests (e.g., Bukit Badindiang, West Sumatra; Sibaganding Tua, North Sumatra) shows that community-based protection helps maintain tree diversity and reduces overexploitation (Santhyami et al. 2021; Sinambela et al. 2021). The persistence of threatened species is strongly linked to local ecological ethics, taboos, and spiritual values that restrict destructive activities (Adam et al. 2019; Cajete 2020; Kosoe et al. 2020). Thus, the forest's conservation importance should be interpreted through both biological indicators and the indigenous knowledge systems that sustain its ecological balance.

Diversity indices

Alpha diversity, measured by the Shannon-Wiener Index (H′), ranged from 2.637 to 2.915 across the seven transects, indicating moderate diversity, as summarized in Table 2. Transect 7 had the highest H′ (2.915). Beta diversity, calculated using the Sørensen Index, revealed high inter-transect similarity (>0.75), indicating homogeneity in forest composition. Species with high Importance Value Index (IVI) included *E. diadenum*, *G. nervosa*, *S. laevigata*, indicating their ecological dominance and contribution to forest structure.

Figure 2. Woody angiosperm species in the Ghimbo Pomuan Sacred Forest, Kampar, Riau Province, Indonesia. A. *Gluta renghas*, B. *Santiria laevigata*, C. *Ochanostachys amentacea*, D. *Ochanostachys amentacea*, E. *Rubroshorea leprosula*, F. *Rubroshorea uliginosa*, G. *Rubroshorea parvifolia*, H. *Rubroshorea balangeran*, I. *Macaranga triloba*, J. *Endospermum diadenum*, K. *Lithocarpus bennettii*, L. *Ixonanthes icosandra*, M. *Litsea erectinervia*, N. *Cryptocarya griffithiana*, O. *Durio zibethinus*, P. *Artocarpus integer*, Q. *Artocarpus odoratissimus*, R. *Syzygium pycnanthum,* S. *Syzygium borneense*, T. *Syzygium leptostemon*, U. *Syzygium cerasiforme*, V. *Syzygium fastigiatum*, W. *Syzygium polyanthum*, X. *Averrhoa carambola*, Y. *Baccaurea macrocarpa*, Z. *Nephelium maingayi*, AA. *Madhuca ovata*, BB. *Palaquium amboinense*, CC. *Mimusops elengi*, DD. *Eurycoma longifolia*

From a regenerative perspective, the stand structure (sapling, pole, tree) indicates that species such as *Macaranga triloba* (Thunb.) Müll.Arg., *Syzygium* sp., and *Rubroshorea* sp. have strong natural regeneration, suggesting that the indigenous forest still maintains healthy ecosystem dynamics and succession. Most recorded species also hold high ecological, economic, and cultural importance for Indigenous communities—as sources of food, medicine, building materials, and symbols in traditional ceremonies. Thus, conserving biodiversity in Ghimbo Pomuan supports both ecological integrity and the continuity of local knowledge and cultural heritage.

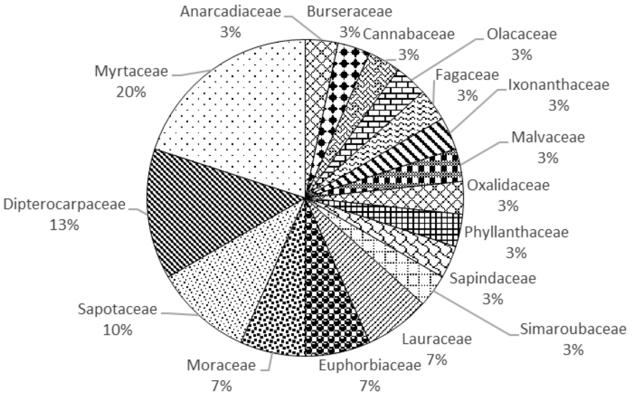

Figure 3. Number of species per family in the of woody angiosperm in the Ghimbo Pomuan Sacred Forest, Kampar, Riau Province, Indonesia

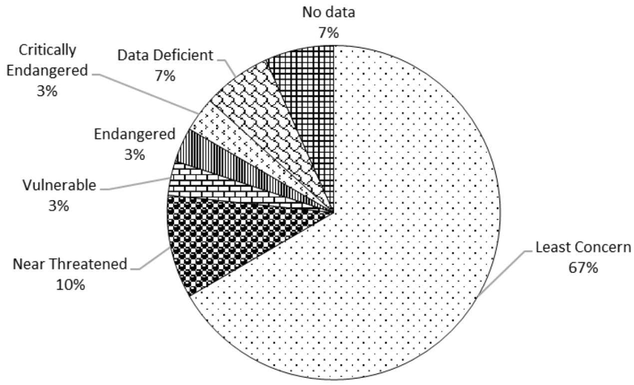

Figure 4. Conservation status composition of woody angiosperm species in Ghimbo Pomuan Sacred Forest, Kampar, Riau Province, Indonesia

The moderate alpha diversity across all transects, coupled with high beta similarity, reflects ecological stability and minimal anthropogenic disturbance, suggesting that indigenous management practices have successfully maintained forest equilibrium. Comparable trends were also reported in other sacred forests of Indonesia (Santhyami et al. 2021; Sinambela et al. 2021) and India (Sharma and Kumar 2020), where cultural restrictions on tree cutting and ritual-based forest use foster stable community composition. In Ghimbo Pomuan, the coexistence of dominant taxa such as *S. laevigata* and *G. nervosa* with regenerating species like *M. triloba* and *Rubroshorea* sp. indicates a dynamic yet balanced ecosystem. This pattern supports the view that traditional governance functions as an effective ecological regulator, where cultural taboos, indigenous ethics, and spiritual beliefs collectively maintain biodiversity and ensure long-term forest resilience.

Cultural classification system

The indigenous people are familiar with the local names of the woody Angiosperm plant species in the Ghimbo Pomuan Sacred Forest. The local names of the plants in the Ghimbo Pomuan sacred forest have been passed down from generation to generation since the time of the ancestors. Some local names have gained widespread recognition nationally, although there are regional variations in pronunciation. For example, the plant known as *pudu* in various regions of the Malay Ocu community is also called *cubodak ayu*, although it is still commonly referred to as *pudu* in some areas. In general, the local names of wood-habituated plants in the Ghimbo Pomuan sacred forest are also immortalized as the names of several hamlets in the Kampar Sub-district area, such as Jawi-jawi, Danto, Tarok, Alay, Padang Merbau, and others.

The Ghimbo Pomuan Sacred Forest has high biodiversity potential and multifunctional benefits, reflecting its vital role in supporting the ecological, economic, cultural, and nutritional sustainability of local communities. The Ghimbo Pomuan Sacred Forest is a sacred forest ecosystem with a wealth of high biodiversity values, including angiosperm woody plants with various potential indirect and direct values. Indirect value of biodiversity, including conservation value (Antongiovanni et al. 2022; Attum et al. 2022; Thorpert et al. 2022), ecological value (Cox and Rodway-Dyer 2022; Recasens et al. 2022), and cultural values (Alho 2008). The direct value of biodiversity, including the value of nutrition or consumption (Costa et al. 2022; Gatti et al. 2022) and economic value or production (Costa et al. 2022; De Valck and Rolfe 2022; Anthony and Morrison-Saunders 2023).

Ecologically, the biodiversity of the Ghimbo Pomuan Sacred Forest maintains canopy structure, supports natural regeneration, and helps stabilize landslide-prone areas, thereby strengthening ecosystem resilience. The forest also provides economic and productive benefits through construction materials, food sources, and phytochemical compounds for traditional medicines and potential industrial use, while offering sustainable natural foods for local consumption.

Culturally, the presence of sacred plants and traditional honeycombs reflects strong spiritual values and Indigenous knowledge. The forest is not only a source of natural resources and livelihood, but also a living space and a heritage of local wisdom. Therefore, conserving the Ghimbo Pomuan Sacred Forest is important not only for ecological reasons but also as a foundation for bioeconomic development and for strengthening the cultural identity of local communities.

This study underscores the importance of culturally grounded indicators for assessing social-ecological resilience. Sterling et al. (2017) argue that sustainability measures must align with local cultures and knowledge systems, while Mikołajczak et al. (2021) show that people's perceptions of nature do not always match their indigenous knowledge, calling for culture-specific conservation strategies. The Ghimbo Pomuan community illustrates this, as customary beliefs directly support ecological stewardship. Similarly, Pinder et al. (2020) found that environmental concern is strongly shaped by early cultural narratives and family values, highlighting the cultural roots of conservation awareness. An overview of the biodiversity value of the Ghimbo Pomuan Sacred Forest is shown in Figure 5.

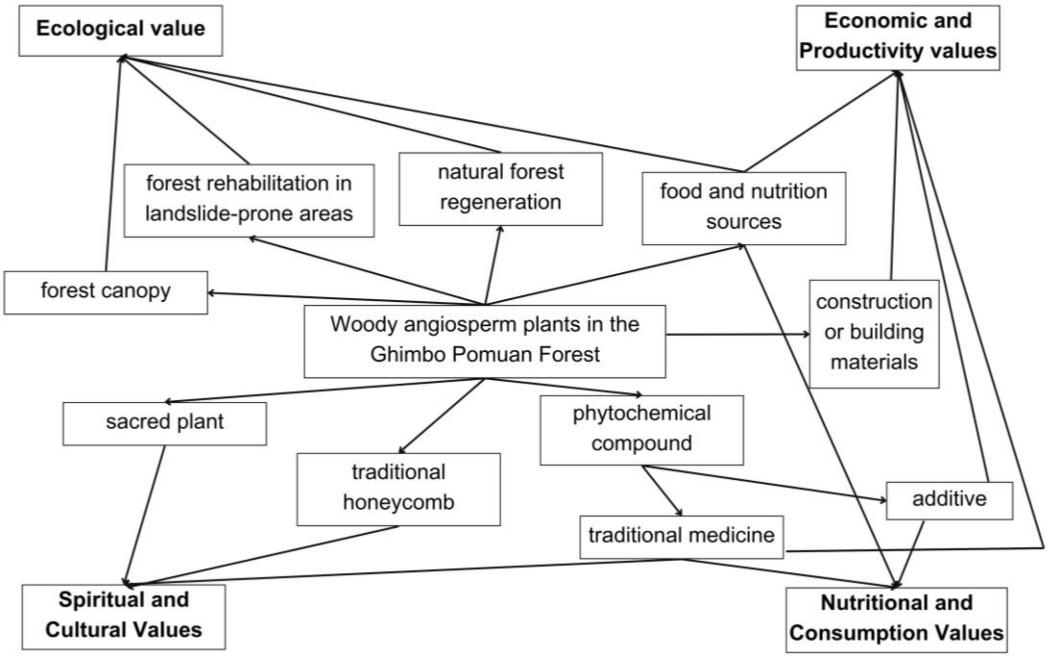

Figure 5. The biodiversity value of Ghimbo Pomuan Sacred Forest, Kampar, Riau Province, Indonesia

Ecological value refers to the essential benefits that ecosystems naturally provide to support life, such as clean air, water, soil fertility, climate control, and biodiversity conservation (Ravi et al. 2023). Meanwhile, conservation value is related to conservation biology and environmental management (Capmourteres and Anand 2016). The species studied demonstrate their ecological and conservation value, including their role in forming canopy structures, protecting the soil, providing food for wildlife, and supporting the natural regeneration of forests. Certain species, such as *Shorea* sp. (*Rubroshorea*) can form a canopy in the forest (Fajri et al. 2020). Species of the genus *Macaranga* exhibit a prominent root system and biomechanical characteristics, making them a representation of tropical pioneer trees that are effectively used for forest rehabilitation in landslide-prone areas (Lee et al. 2020). Additionally, *Mimusops elengi* L. can adapt to various soil types, supported by its large and sturdy root system (Srivastava et al. 2024).

Shorea (*Rubroshorea*) *laevigata* includes edible wild plants (Suwardi et al. 2022). *Averrhoa carambola* L. becomes a food source in the forest (Suwardi et al. 2020). *G. renghas* has the potential as a bio-larvicide for vector control (Zuharah et al. 2021) and can form symbiosis with mycorrhizae, such as *Acaulospora* sp. and *Glomus* sp., which supports its growth (Ilham et al. 2019). *Eurycoma longifolia* Jack has the highest germination of recalcitrant seeds in a mixed medium of sand and soil, while pure husk charcoal supports optimal growth (Susilowati et al. 2023a). *Rubroshorea parvifolia* (Dyer) P.S.Ashton & J.Heck. and *G. nervosa* play a crucial role in supporting the natural regeneration of tropical forests, as they are dominant in various vegetation and regenerative strata in some tropical forest areas (Fambayun et al. 2019). *Shorea laevigata* also exhibits strong dominance in the early growth phase (stakes), indicating successful early regeneration (Susilowati et al. 2023b).

Spiritual and cultural values are also closely attached to biodiversity and shape how traditional societies interpret, manage, and preserve nature for generations (Workneh 2023). Some societies consider certain plants sacred, such as *G. renghas* (Partasasmita et al. 2020). Group *Shorea* (*Rubroshorea*) sp., *G. renghas,* and *Syzygium* sp. are used by specific local communities to manufacture honey bee hives (Ayu et al. 2024). *Artocarpus odoratissimus* Blanco is widely used in traditional medicine because nearly all its parts possess pharmacological properties (Yulianti et al. 2022). Leaf *Syzygium polyanthum* (Wight) Walp. has long been used as an ingredient in traditional Indonesian medicine due to its efficacy in treating peptic ulcers, hypertension, diabetes, hyperuricemia, diarrhea, gastritis, skin diseases, and inflammation (Ramli et al. 2023).

The nutritional value and consumption are also contributed to by various species as a means of fulfilling human nutritional and food needs (Costa et al. 2022). *Eurycoma longifolia* (*tongkat ali*) is a widely used Southeast Asian medicinal plant whose main compound, eurycomanone, has demonstrated significant anticancer activity, but further research is still needed to clarify its molecular mechanisms and therapeutic potential (Jothi et al. 2023). Meranti (*Rubroshorea* sp.) has the potential to be a source of non-timber forest products because the content of phytochemical compounds in the bark of the trunk is beneficial as an antidiabetic, antioxidant, and anticancer (Wardani et al. 2021). Durian has nutritional value and is consumed by some local communities, who have planted it in agroforestry systems (Afentina et al. 2021). *Artocarpus odoratissimus* Blanco, a fruit, is a potential food source that can be developed into a local crop with economic value (Wahyuningtyas et al. 2024).

Economic value is derived from the benefits provided by various species that support biodiversity and ecosystems (De Valck and Rolfe 2022). Meranti (*Shorea* spp.) is used as a construction or building material, such as walls, door and window panels, and floors, due to its strong and durable wood (Wardani et al. 2021). The bark extracts of *G. renghas* exhibit high larvicide activity, indicating that the same or similar bioactive compounds may also be responsible for their irrigative properties (Yousaf and Zuharah 2015). Species in the genus *Litsea* contain alkaloids, glycosides, and terpenoids that exhibit a variety of biological activities, including antimicrobial, antioxidant, and anti-inflammatory properties, which may contribute to their potential as larvicides (Zhang et al. 2023). Phytochemical compounds from Meranti (*Rubroshorea* sp.), which have been shown to possess antidiabetic, antioxidant, and anticancer properties (Wardani et al. 2021), have the potential to be developed into a commercial drug. The potential of durian will provide economic and commercial benefits for the community (Afentina et al. 2021; Tata et al. 2022).

Indigenous conservation practices

It highlights the integration of indigenous conservation mechanisms, such as taboos and customary rules, with formal systems (IUCN categories and social forestry policies), suggesting a pathway for biocultural conservation. Woody angiosperms, as a group of flowering plants, are a vital part of biodiversity that plays an ecological, spiritual, cultural, nutritional, and economic role, and is also tied to indigenous knowledge. Indigenous knowledge in the form of principles, skills, practices, rituals, and customs developed by a particular race or tribe and passed down from generation to generation (Adam et al. 2019; Cajete 2020). This knowledge is also reflected in the local naming of some organisms (Wilder et al. 2016). Moreover, indigenous knowledge can take the form of social systems such as myths, taboos (prohibitions), norms, and beliefs that function to maintain environmental balance (Kosoe et al. 2020).

The Ghimbo Pomuan Sacred Forest is not only a center of biological diversity but also a landscape imbued with deep cultural significance, shaped by the traditions of the Kanagarian Kampa indigenous community. The name "Pomuan," meaning "a place of meeting," symbolizes both ecological and spiritual convergence, where wildlife and ancestral spirits coexist in harmony. This cultural dimension underscores the forest's dual role as an ecological refuge and a sacred space. Oral histories recount that Ghimbo Pomuan once served as a sanctuary during periods of colonial conflict. Local governance of the forest is collective and hereditary, maintained through traditional leadership under the authority of the *ninik mamak* and customary institutions. The coronation of *Datuak* leaders continues to serve as a living ritual that binds social governance with environmental stewardship. Such traditions parallel community-based conservation systems found in other sacred forests across Asia and Africa (Sharma and Kumar 2020; Sen and Bhakat 2022).

Customary norms prohibit tree felling, hunting, and offensive behavior, while allowing limited use of non-timber forest products for communal benefit. Key species such as *Rubroshorea* spp., *G. renghas*, and *Syzygium* spp. are protected by taboo and myth. These beliefs, although intangible, function as practical conservation tools—akin to sacred groves in Ghana, India, and Iran (Shakeri et al. 2021; Akalibey et al. 2024). The forest is governed by a tripartite legal system, comprising *Tigo Tungku Sajoangan*, which integrates customary, religious, and state laws. Specific zones within the forest, such as Ghimbo Bonca Lida, are strictly protected and classified as "*imbo*" or forbidden forests. This spatial governance supports biodiversity by maintaining canopy cover and restricting degradation. Spiritual beliefs about ancestral spirits and sacred animals influence respectful behavior in the forest. Symbolic permissions—like greetings or prayers—are required before entry, a practice comparable to rituals in Leuweung Kolot (Banten) or *Ubarampe* (Somongari), which combine conservation with cultural performance (Partasasmita et al. 2020; Adinugraha et al. 2024).

The study highlights that sacred forests serve as biodiversity refugia, preserving canopy species and rare taxa, such as *G. renghas* (NT). These findings align with the literature, which shows that sacred forests host comparable or greater biodiversity than protected areas (Sullivan et al. 2023; Undaharta et al. 2025). Sacred forests have been shown to have similar or higher levels of biodiversity compared to non-sacred forests, primarily benefiting plant species (Sullivan et al. 2023). Indigenous peoples, such as the Mullu Kuruman, utilise diverse plant species for food and medicine, demonstrating the importance of traditional ecological knowledge in biodiversity conservation (Anju and Kumar 2024). The Kogui people of Colombia exemplify successful biodiversity conservation through their cosmovision and nature-based governance systems, highlighting the role of indigenous knowledge in sustainable management (Pyhälä 2024). Similar patterns have also been observed in African sacred groves, such as in Nigeria, where traditional beliefs effectively preserve endemic flora (Onyekwelu et al. 2024). The erosion of indigenous knowledge and practices poses a threat to the conservation of sacred sites. Documenting and integrating these practices into formal conservation strategies are essential (Parween and Marchant 2022)

This study is limited to indigenous naming and ecological roles of woody angiosperms. It did not assess medicinal use or ritual-specific plant species. Future studies should explore how taboos and customs influence regeneration and forest dynamics. There is also potential to integrate ethnobiological perspectives into science education (Adinugraha 2022), particularly in biodiversity curricula that reflect Indonesia's biocultural richness (Azis et al. 2020; Zubaidah and Arsih 2021). Ultimately, the Ghimbo Pomuan sacred forest exemplifies how indigenous knowledge systems can inform sustainable forest governance, enhance conservation, and contribute to environmental education across tropical landscapes (Parween and Marchant 2022; Pyhälä 2024). Despite these limitations, the findings offer valuable insights into how indigenous ecological knowledge and sacred beliefs shape species conservation in tropical forests. These results support the case for integrating indigenous governance into formal forest management strategies, particularly in efforts to recognize sacred forests under Indonesia's social forestry program. Future research should also examine long-term ecological monitoring, regeneration rates under customary taboos, and the role of ritual-based forest zoning. The integration of ethnobiological knowledge into environmental education and conservation curricula also holds promise for reinforcing both cultural heritage and biodiversity protection in Indonesia and other tropical regions.

In conclusion, this study highlights the role of woody angiosperms in the Ghimbo Pomuan Sacred Forest as both ecological keystones and cultural assets maintained through indigenous knowledge. The presence of several ecologically significant species, such as *Rubroshorea* spp., *G. renghas*, and *Syzygium* spp. show that biodiversity persistence in this sacred forest is strongly supported by customary prohibitions, sacred values, and spatial governance rooted in indigenous ecological knowledge. The community's interpretation of "Pomuan" as "a place of meeting" reflects the integration of ecological, cultural, and spiritual dimensions within local stewardship. Overall, the findings demonstrate that rituals, taboos, and customary institutions support biocultural conservation mechanisms that complement formal approaches, such as the IUCN Red List and Indonesia's social forestry program. These findings underscore the critical role of sacred forests as biocultural refuges and provide empirical support for strengthening community-based forest conservation policies in Indonesia. We recommend that community-based practices be formally recognized in regional forest management policies through participatory zoning, legal protection of sacred forests, and integration into conservation education. By bridging indigenous knowledge and scientific approaches, sacred forests can serve as replicable models for biodiversity protection, cultural continuity, and sustainable livelihoods in Sumatra and other tropical regions.

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REFERENCES

Adam AA, Othman N, Halim AA, Ismail SR, Samah AA. 2019. The practice of biodiversity–related indigenous knowledge in Kota Belud, Sabah: A preliminary study. Pertanika J Soc Sci Humanit 27 (S1): 215-225.

Adinugraha F, Zubaidah S, Lestari SR, Chua KH. 2024. Ethnobiology of plants and animals used as ubarampe in the Kepungan tradition of the Javanese community of Somongari, Purworejo District, Indonesia. Biodiversitas 25 (8): 2521-2532. DOI: 10.13057/biodiv/d250824.

Adinugraha F. 2022. An approach to local wisdom and cultural in Biology learning. Proc 3rd Int Conf Edu Sci (ICES 2021), Jakarta. DOI: 10.4108/eai.17-11-2021.2318660.

Afentina Y, Yanarita, Indrayanti L, Rotinsulu JA, Hidayat N, Sianipar J. 2021. The potential of agroforestry in supporting food security for peatland community – A case study in the Kalampangan Village, Central Kalimantan. J Ecol Eng 22 (8): 123-130. DOI: 10.12911/22998993/140260.

Akalibey S, Hlaváčková P, Schneider J, Fialová J, Darkwah S, Ahenkan A. 2024. Integrating indigenous knowledge and culture in sustainable forest management via global environmental policies. J For Sci 70 (6): 265-280. DOI: 10.17221/20/2024-JFS.

Akhmar AM, Rahman F, Supratman S, Hasyim H, Nawir M. 2022. Poured from the sky: The story of traditional ecological knowledge in Cérékang Forest conservation. For Soc 6 (2): 527-546. DOI: 10.24259/fs.v6i2.15176.

Albuquerque UP, Cruz da Cunha LVF, de Lucena RFP, Alves RRN. 2014. Methods and Techniques in Ethnobiology and Ethnoecology. Springer, New York. DOI: 10.1007/978-1-4614-8636-7.

Alho CJR. 2008. The value of biodiversity. Braz J Biol 68 (4): 1115-1118. DOI: 10.1590/S1519-69842008000500018.

Anju T, Kumar A. 2024. Traditional ecological knowledge and medicinal plant diversity usage among the Mullu Kuruman tribes of Wayanad district of Kerala, India and its implications for biodiversity conservation in the face of climate change. Trees For People 16: 100595. DOI: 10.1016/j.tfp.2024.100595.

Anthony SJ, Morrison-Saunders A. 2023. Analysing corporate forest disclosure: How does business value biodiversity? Bus Strategy Environ 32 (1): 624-638. DOI: 10.1002/bse.3164.

Antongiovanni M, Venticinque EM, Tambosi LR, Matsumoto M, Metzger JP, Fonseca CR. 2022. Restoration priorities for Caatinga dry forests: Landscape resilience, connectivity and biodiversity value. J Appl Ecol 59 (9): 2287-2298. DOI: 10.1111/1365-2664.14131.

Attum O, Malkawi S, Hamidan N. 2022. Factors contributing to the biodiversity value of an archaeological landscape in Jordan. Herpetol J 32 (3): 102-108. DOI: 10.33256/32.3.102108.

Ayu M, Lovadi I, Gusmalawati D. 2024. *Tikung* ethnobotany of the Melayu community of Baturawan Village, Kapuas Hulu Regency in traditional honey cultivation. Bioscientist J Ilmu Biol 12 (1): 612-622. DOI: 10.33394/bioscientist.v12i1.10004. [Indonesian]

Azis S, Zubaidah S, Mahanal S, Batoro J, Sumitro SB. 2020. Local knowledge of traditional medicinal plants use and education system on their young of Ammatoa Kajang Tribe in South Sulawesi, Indonesia. Biodiversitas 21 (9): 3989-4002. DOI: 10.13057/biodiv/d210909.

Bahadur B, Rajam MV, Sahijram L, Krishnamurthy KV. 2015. Plant Biology and Biotechnology: Plant Diversity, Organization, Function and Improvement Vol. 1. Springer, New Delhi. DOI: 10.1007/978-81-322-2286-6.

Berame JS, Bulay ML, Mercado RM. 2021. Sustaining angiosperms' diversity of Bood Promontory and Eco-Park, Butuan City, Philippines: Step towards a community-based protection management program. Biodiversitas 22 (6): 2519-2527. DOI: 10.13057/biodiv/d220662.

Cajete GA. 2020. Indigenous science, climate change, and indigenous community building: A framework of foundational perspectives for indigenous community resilience and revitalization. Sustainability 12 (22): 9569. DOI: 10.3390/su12229569.

Capmourteres V, Anand M. 2016. "Conservation value": A review of the concept and its quantification. Ecosphere 7 (10): e01476. DOI: 10.1002/ecs2.1476.

Costa CP, Patinha S, Rudnitskaya A, Santos SAO, Silvestre AJD, Rocha SM. 2022. Sustainable valorization of *Sambucus nigra* L. berries: From crop biodiversity to nutritional value of juice and pomace. Foods 11 (1): 104. DOI: 10.3390/foods11010104.

Cox L, Rodway-Dyer S. 2022. The underappreciated value of brownfield sites: Motivations and challenges associated with maintaining biodiversity. J Environ Plan Manag 66 (9): 2029-2027. DOI: 10.1080/09640568.2022.2050683.

De Valck J, Rolfe J. 2022. Reviewing the use of proxies to value coastal and marine biodiversity protection: The Great Barrier Reef in Australia. Mar Policy 136: 104890. DOI: 10.1016/j.marpol.2021.104890.

Delaney S, von Wettberg EJB. 2023. Toward the next angiosperm revolution: Agroecological food production as a driver for biological diversity. Elementa 11 (1): 00134. DOI: 10.1525/elementa.2022.00134.

Fajri M, Pratiwi, Ruslim Y. 2020. The characteristics of *Shorea macrophylla*'s habitat in Tane' Olen, Malinau District, North Kalimantan Province, Indonesia. Biodiversitas 21 (8): 3454-3462. DOI: 10.13057/biodiv/d210806.

Fambayun RA, Heriyanto NM, Wardani M. 2019. Ecological aspects of meranti kunyit (*Shorea macroptera* Dyer) in Rantau Bertuah Forest, Siak Regency, Riau Province and the implication for forest

management and conservation. J Penelit Kehutanan Wallacea 9 (2): 83-92. DOI: 10.18330/jwallacea.2022.vol11iss1pp1-11.
Fikri MZ. 2023. Restoring customary forest rights through agrarian reform: Case study of the Kampar Community, Indonesia. Southeast Asian Stud 12 (1): 47-87. DOI: 10.20495/seas.12.1_47.
Gatti N, Gomez MI, Bennett RE, Sillett TS, Bowe J. 2022. Eco-labels matter: Coffee consumers value agrochemical-free attributes over biodiversity conservation. Food Qual Prefer 98: 104509. DOI: 10.1016/j.foodqual.2021.104509.
Harada K, Habib M, Sakata Y, Maryudi A. 2022. The role of NGOs in recognition and sustainable maintenance of customary forests within indigenous communities: The case of Kerinci, Indonesia. Land Use Policy 113: 105883. DOI: 10.1016/j.landusepol.2021.105883.
Ikhsani H, Sadjati E, Azwin. 2023. Spatial analysis of the existence and distribution of medicinal plants in Ghimbo Pomuan Customary Forest, Kampar District, Riau Province. J Glob Sustain Agric 4 (1): 45-54. DOI: 10.32502/jgsa.v4i1.7335. [Indonesian]
Ilham M, Malik AA, Amri A, Akib MA. 2019. Isolation and identification of native mikoriza morphology on the rhizosphere *Gluta rengas* L. in Jompie Botanical Garden. Agrotech J 4 (2): 69-74. DOI: 10.31327/atj.v4i2.1094.
Jothi S, Parumasivam T, Mohtar N. 2023. *Eurycoma longifolia*: An overview on the pharmacological properties for the treatment of common cancer. J Public Health Afr 14 (S1), 2495. DOI: 10.4081/jphia.2023.2495.
Kosoe EA, Adjei POW, Diawuo F. 2020. From sacrilege to sustainability: The role of indigenous knowledge systems in biodiversity conservation in the Upper West Region of Ghana. GeoJournal 85 (4): 1057-1074. DOI: 10.1007/s10708-019-10010-8.
Kusumoto B, Chao A, Eiserhardt WL, Svenning J-C, Shiono T, Kubota Y. 2023. Occurrence-based diversity estimation reveals macroecological and conservation knowledge gaps for global woody plants. Sci Adv 9 (40): eadi6467. DOI: 10.1126/sciadv.adi6467.
Lee JT, Chu MY, Lin YS, Kung KN, Lin WC, Lee MJ. 2020. Root traits and biomechanical properties of three tropical pioneer tree species for forest restoration in landslide areas. Forests 11 (2): 179. DOI: 10.3390/f11020179.
Liu X, Wang S, Cui L, Zhou H, Liu Y, Meng L, Chen S, Xi X, Zhang Y, Kang W. 2023. Flowers: Precious food and medicine resources. Food Sci Hum Well 12 (4): 1020-1052. DOI: 10.1016/j.fshw.2022.10.022.
Londe V, Reid JL, Farah FT, Rodrigues RR, Martins FR. 2022. Estimating optimal sampling area for monitoring tropical forest restoration. Biol Conserv 269: 109532. DOI: 10.1016/j.biocon.2022.109532.
Mikołajczak K, Lees AC, Barlow J, Sinclair F, Almeida OT, de Souza AC, Parry L. 2021. Who knows, who cares? Untangling ecological knowledge and nature connection among Amazonian colonist farmers. People Nat 3: 431-445. DOI: 10.1002/pan3.10214.
Mo L, Crowther TW, Maynard DS et al. 2024. The global distribution and drivers of wood density and their impact on forest carbon stocks. Nat Ecol Evol 8: 2195-2212. DOI: 10.1038/s41559-024-02564-9.
Mulyadi A, Dede M, Widiawaty MA. 2022. The role of tradisional belief and local wisdom in forest conservation. J Geografi Gea 22 (1): 55-66. DOI: 10.17509/gea.v22i1.43702.
Odum EP, Barrett GW. 2004. Fundamentals of ecology. 5th ed. Cengage Learning, Belmont.
Onyekwelu JC, Agbelade AD, Stimm B, Mosandl R. 2024. Role of sacred groves in southwestern Nigeria in biodiversity conservation, biomass and carbon storage. Environ Monit Assess 196: 269. DOI: 10.1007/s10661-024-12407-6.
Partasasmita R, Cahyani NT, Iskandar J. 2020. Local knowledge of the community in Cintaratu Village, Pangandaran, Indonesia on traditional landscapes for sustainable land management. Biodiversitas 21 (8): 3606-3616. DOI: 10.13057/biodiv/d210825.
Parween R, Marchant R. 2022. Traditional knowledge and practices, sacred spaces and protected areas, technological progress: Their success in conserving biodiversity. Conserv Sci Pract 4 (5): e12643. DOI: 10.1111/csp2.12643.
Perner T, Wachtier M. 2020. The arising of the monocots. In: Wachtler M, Thomas P (eds.) The Origin and Evolution of Angiosperms: Early Permian Flowering Plants. Dolomythos Museum, South Tyrol.
Pinder J, Fielding KS, Fuller RA. 2020. Conservation concern among Australian undergraduates is associated with childhood socio-cultural experiences. People Nat 2 (4): 1158-1171. DOI: 10.1002/pan3.10145.
Pyhälä A. 2024. Decolonizing nature conservation according to natural law: Learning from the Kogui. AlterNative 20 (3): 484-493. DOI: 10.1177/11771801241255697.
Rahmayani, Palennari M, Rachmawaty. 2020. Flora Angiospermae. Ellunar Publisher, Bandung. [Indonesian]
Ramli S, Wong JX, Rukayadi Y. 2023. Antimicrobial activity of *Syzygium polyanthum* Wight (Walp.) extract against foodborne pathogens in food: A potential antimicrobial agent for natural food washing solution. Malays J Fundam Appl Sci 19 (2): 219-235. DOI: 10.11113/mjfas.v19n2.2828.
Ratnaningsih AT, Aisyah S, Warningsih T, Saam Z, Zulkarnaini, Syahza A. 2023. Carbon economic valuation of pole trees and trees in the Ghimbo Pomuan Indigenous Forest, Kampar District, Riau Province. Wahana Forestra: J Kehutanan 18 (2): 71-83. DOI: 10.31849/forestra.v18i2.14075. [Indonesian]
Ravi, Putri EE, Jayaprakash, Hamidi M. 2023. Economic value of ecosystem services. E3S Web Conf 464: 18002. DOI: 10.1051/e3sconf/202346418002.
Recasens RM, Carrasco J, Lisón F, Pais C, Miranda A, de la Barra F, Weintraub A. 2022. Combining optimization and fire simulation modeling to protect biodiversity values at a landscape scale. Proc 2022 IEEE Latin American Conf Comput Intellig (LA-CCI). DOI: 10.1109/LA-CCI54402.2022.9981527.
Riziqo RA, Purba KNK, Surbakti BR, Fahlisyah M, Purba IS, Sembiring SA. 2024. Story of conservation: Integrating ethnobotanical knowledge, healer, and sacred area in Daulu–Karonese, North Sumatera. Perspektif 13 (1): 79-91. DOI: 10.31289/perspektif.v13i1.10749.
Santhyami X, Basuki A, Patria MP, Abdulhadi R. 2021. Tree community structure and aboveground carbon stock of sacred forest in Pasaman, West Sumatera. Biotropia 28 (3): 253-262. DOI: 10.11598/btb.2021.28.3.1416.
Sauquet H, Ramírez-Barahona S, Magallón S. 2022. What is the age of flowering plants? J Exp Bot 73 (12): 3840-3853. DOI: 10.1093/jxb/erac130.
Sen UK, Bhakat RK. 2022. Biocultural approaches to sustainability: Role of indigenous knowledge systems in biodiversity conservation of West Bengal, India. Time Mind 15 (2): 237-253. DOI: 10.1080/1751696X.2022.2085527.
Shadrina A, Ratnaningsih AT, Ikhsani H. 2023. Utilization of non-timber forest products in the Ghimbo Pomuan Customary Forest, Kampar District, Riau Province. Green Tech: Ilmu Lingkungan 1 (1): 11-20. [Indonesian]
Shakeri Z, Mohammadi-Samani K, Bergmeier E, Plieninger T. 2021. Spiritual values shape taxonomic diversity, vegetation composition, and conservation status in woodlands of the Northern Zagros, Iran. Ecol Soc 26 (1): 30. DOI: 10.5751/ES-12290-260130.
Sharma S, Kumar R. 2020. Sacred groves of India: Repositories of a rich heritage and tools for biodiversity conservation. J For Res 32 (3): 899-916. DOI: 10.1007/s11676-020-01180-0.
Sinambela SN, Badaruddin, Slamet B. 2021. The existence and role of traditional cultural beliefs in conserving Sibaganding Tua sacred forest. IOP Conf Ser Earth Environ Sci 782 (3): 032010. DOI: 10.1088/1755-1315/782/3/032010.
Soendjoto MA, Sudiarta IWK, Cangara MIZ, Patria WA, Riefani MK. 2025. Diversity and composition of plants in ex-mining revegetation lands for cement raw materials in South Kalimantan, Indonesia. Biodiversitas 26 (2): 670-680. DOI: 10.13057/biodiv/d260214.
Srivastava S, Siddiqui MA, Arif M, Javed A, Khan A. 2024. *Mimusops elengi*: A comprehensive review. Intell Pharm 2: 672-680. DOI: 10.1016/j.ipha.2023.11.007.
Stephens RE, Gallagher RV, Dun L, Cornwell W, Sauquet H. 2023. Insect pollination for most of angiosperm evolutionary history. New Phytol 240 (2): 880-891. DOI: 10.1111/nph.18993.
Sterling E, Ticktin T, Morgan TK, Cullman G, Alvira D, Andrade P, Bergamini N, Betley E, Burrows K, Caillon S, Claudet J. 2017. Culturally grounded indicators of resilience in social-ecological systems. Environ Soc Adv Res 8 (1): 63-95. DOI: 10.3167/ares.2017.080104.
Sullivan MK, Browne L, Zuluaga JCP, Liu J, Surendra A, Estrada-Villegas S. 2023. Sacred forest biodiversity conservation: A meta-analysis. Conserv Sci Pract 5 (3): e13055. DOI: 10.1111/csp2.13055.
Suryanto P, Sadono R, Yohanifa A, Widyawan MH, Alam T. 2021. Semi-natural regeneration and conservation in agroforestry system models on small-scale farmers. Biodiversitas 22 (2): 858-865. DOI: 10.13057/biodiv/d220240.
Susilowati A, Rachmat HH, Yulita KS, Ginting IM, Iswanto AH, Sucipto T. 2023a. Seed morphology and germination of pasak bumi (*Eurycoma longifolia*). IOP Conf Ser Earth Environ Sci 1241 (1): 012010. DOI: 10.1088/1755-1315/1241/1/012010.

Susilowati A, Rachmat HH, Yulita KS, Wijaya K. 2023b. Floristic composition and structure of *Eurycoma longifolia* habitat in Muka Kuning Nature Tourism Park, Riau Islands, Indonesia. Biodiversitas, 24 (5): 2836-2842. DOI: 10.13057/biodiv/d240537.

Suwardi AB, Navia ZI, Harmawan T, Seprianto, Syamsuardi, Mukhtar E. 2022. Diversity of wild edible fruit plant species and their threatened status in the Aceh Province, Indonesia. Biodiversitas 23 (3): 1310-1318. DOI: 10.13057/biodiv/d230315.

Suwardi AB, Navia ZI, Harmawan T, Syamsuardi, Mukhtar E. 2020. Ethnobotany and conservation of indigenous edible fruit plants in South Aceh, Indonesia. Biodiversitas 21 (5): 1850-1860. DOI: 10.13057/biodiv/d210511.

Tata HL, Nuroniah HS, Ahsania DA, Anggunira H, Hidayati SN, Pratama M, Istomo I, Chimner RA, van Noordwijk M, Kolka R. 2022. Flooding tolerance of four tropical peatland tree species in a nursery trial. PLoS ONE 17 (4): e0262375. DOI: 10.1371/journal.pone.0262375.

Thorpert P, Rayner J, Haaland C, Englund J-E, Fransson A-M. 2022. Exploring the integration between colour theory and biodiversity values in the design of living walls. Front Ecol Evol 10: 804118. DOI: 10.3389/fevo.2022.804118.

Undaharta NKE, Martini F, Wee AKS. 2025. Comparable biodiversity and demographic structure between sacred groves and protected forests with *Dipterocarpus hasseltii* reveal conservation value of customary forests in Bali, Indonesia. Biodivers Conserv 34: 3147-3162. DOI: 10.1007/s10531-024-02885-y.

Wahyuningtyas RS, Humaida N, Hani A, Aziza LN, Gunawan G, Fitriani A. 2024. Potential and challenges of utilizing *Artocarpus odoratissimus* (Binturung) fruit in Kalimantan. IOP Conf Ser Earth Environ Sci 1315 (1): 012026. DOI: 10.1088/1755-1315/1315/1/012026.

Wardani M, Denny, Susilo A. 2021. A review: Prospective study of non-timber forest product uses in three *Shorea* species. IOP Conf Ser Earth Environ Sci 914 (1): 012053. DOI: 10.1088/1755-1315/914/1/012053.

Wilder B, O'Meara C, Monti L, Nabhan GP. 2016. The importance of indigenous knowledge in curbing the loss of language and biodiversity. BioScience 66 (6): 499-509. DOI: 10.1093/biosci/biw026.

Wilder B. 2016. The importance of indigenous knowledge in curbing the loss of language and biodiversity. BioScience 66 (6): 499-509. DOI: 10.1093/biosci/biw026.

Workneh TC. 2023. Rethinking cultural and spiritual values in biodiversity conservation among the Konso people of South-Western Ethiopia. Ethiop Renaiss J Soc Sci Humanit 10 (1): 1-19. DOI: 10.4314/erjssh.v10i1.1.

Ying X. 2021. Impact of ecological importance of angiosperms. Res Rev J Bot Sci 10 (3): 2347.

Yousaf A, Zuharah WF. 2015. Lethal response of the dengue vectors to the plant extracts from family Anacardiaceae. Asian Pac J Trop Biomed 5 (10): 812-818. DOI: 10.1016/j.apjtb.2015.05.016.

Yulianti I, Padlilah R, Ariyanti R, Retnowati Y, Febrianti S, Purnamasari A. 2022. Mapping review of the potential of tarap plants (*Artocarpus odoratissimus*) for health. Int J Health Sci 6: 2351-2357. DOI: 10.53730/ijhs.v6ns4.7062.

Zhang L, Dong L, Liu Q, Liu Z. 2020. Spatial patterns and interspecific associations during natural regeneration in three types of secondary forest in the central part of the Greater Khingan Mountains, Heilongjiang Province, China. Forests 11 (2): 152. DOI: 10.3390/f11020152.

Zhang Y, Pan Z, Wu K, Yan G, Xu H, Gong Q, Ni L. 2023. Research progress on the chemical constituents and pharmacological activity of *Litsea cubeba* (Lour) Pers. Rec Nat Prod 17 (4): 577-594. DOI: 10.25135/rnp.399.2305.2774.

Zubaidah S, Arsih F. 2021. Indonesian culture as a means to study science. AIP Conf Proc 2330: 020029. DOI: 10.1063/5.0043173.

Zuharah WF, Yousaf A, Ooi KL, Sulaiman SF. 2021. Larvicidal activities of family Anacardiaceae on *Aedes* mosquitoes (Diptera: Culicidae) and identification of phenolic compounds. J King Saud Univ Sci 33 (5): 101471. DOI: 10.1016/j.jksus.2021.101471.